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PROBLEMS OF ENERGY SUPPLY IN THE ARCTIC REGIONS

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This paper examines the current problems of energy supply in the Arctic regions and analyzes their main causes. The experience of the EU, USA and Japan on the use of renewable energy sources is presented. Ways to improve the efficiency of energy supply in the Arctic are shown.

Keywords: renewable energy, alternative energy, Arctic, energy supply, electricity, wind energy, solar energy, nuclear energy, bioenergy.

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Introduction

Today, the Arctic is characterized, on the one hand, by a huge volume of proven hydrocarbon reserves (the main sources of electricity in the world), and on the other – by serious problems in supply of electricity to the region. The northernmost regions of Russia are not included in the centralized power supply system (via high-voltage transmission lines) and are traditionally supplied with electricity from outdated diesel generators and small coal-fired stations (Fig. 1).

Fuel is delivered to the Arctic as part of the so-called "Northern delivery", and due to the high remoteness of the Northern regions, limited delivery times in the summer and the obsolescence of existing diesel generators, the cost of electricity for them is very high [1]. In addition, due to frequent interruptions in supplies, the local population is forced to keep diesel fuel reserves for an average of 1.5-2 years. Diesel power plants have low efficiency and remarkably high cost of electricity production, which reaches 80-120 rubles per KW/hour.

Tariffs for electricity in isolated power supply systems in the Far North regions today amount to 22-237 rubles/kWh, which is 5-55 times higher than the average for Russia. At the same time, for comparison, if you take the average price of electricity in the zone of centralized energy supply in the country — it is 3-4 rubles per kWh for the end user [2].

Several decades ago the inclusion of the Arctic and other sparsely populated distant areas of the country into the centralized power supply system was considered to be inefficient and too expensive project. At the same time, the high cost of electricity production entails the need for budget subsidies to contain tariffs for the population (covering the difference between the tariff for the population and the required gross revenue). The total amount of state subsidies is estimated in the hundreds of billions of rubles, and the total cost of energy supply to all consumers in the 15 regions of the Far North today is 1.7 trillion rubles.

The lack of electricity and its high cost strongly constrain the pace of development of the Arctic region and make it less comfortable and attractive for the population.

Estimation of energy supply costs in the regions of the Far North of the Russian Federation.

According to official data, the number of decentralized power supply systems, with high electricity costs, in the regions of the

Far North, which serve more than 11 million people, exceeds several thousands. In total, more than 30 thousand settlements are powered by local power supply systems today. More than 6,000 among them have population of more than 500 people, more than 1,000 settlements have population of more than 2,000 people, and 580 settlements have population of more than 3,000 people [3]. At the same time, the total cost of energy supply to all consumers in 15 regions of the Far North is 1.7 trillion rubles. A significant part (two-thirds) of energy supply costs are incurred by large-scale industry and pipeline systems. Revenues of utility organizations from the sale of electricity, heat and natural gas are equal to 464 billion rubles. The total expenditures of budgets of all the levels for financing energy supply to the Far North regions in 2016 accounted to more than 150 billion rubles. The share of budget expenditures in the payment for services of energy supply organizations in many regions of the Far North exceeds 30%, and in some cases – even 60%, with an average level of about 20% in Russia. The amount of cross-subsidies and losses of companies that supply energy to consumers in the Far North exceeds 40 billion rubles. About half of this amount is spent on subsidizing consumers of territories with isolated energy supply systems. In almost all regions of the Far North (with the exception of those producing oil and gas), the share of energy supply costs in GRP (Gross Regional Product) is 20-37% and exceeds the threshold of economic availability of energy, which does not allow the economy to develop dynamically. For localities with isolated power supply systems, the ratio of energy costs to municipal product often exceeds 40 % [4].

Thus, we can conclude that the regions of the Far North and the Arctic especially need to implement innovative energy-efficient solutions, as well as modern autonomous power plants that use much cheaper renewable energy sources. It is here, in these regions, that the introduction of alternative renewable energy technologies should not only pay off, but also significantly reduce budget expenditures on subsidizing energy consumption. And the potential for such modernization lies precisely in the current high budget costs for energy supply to the Arctic regions.

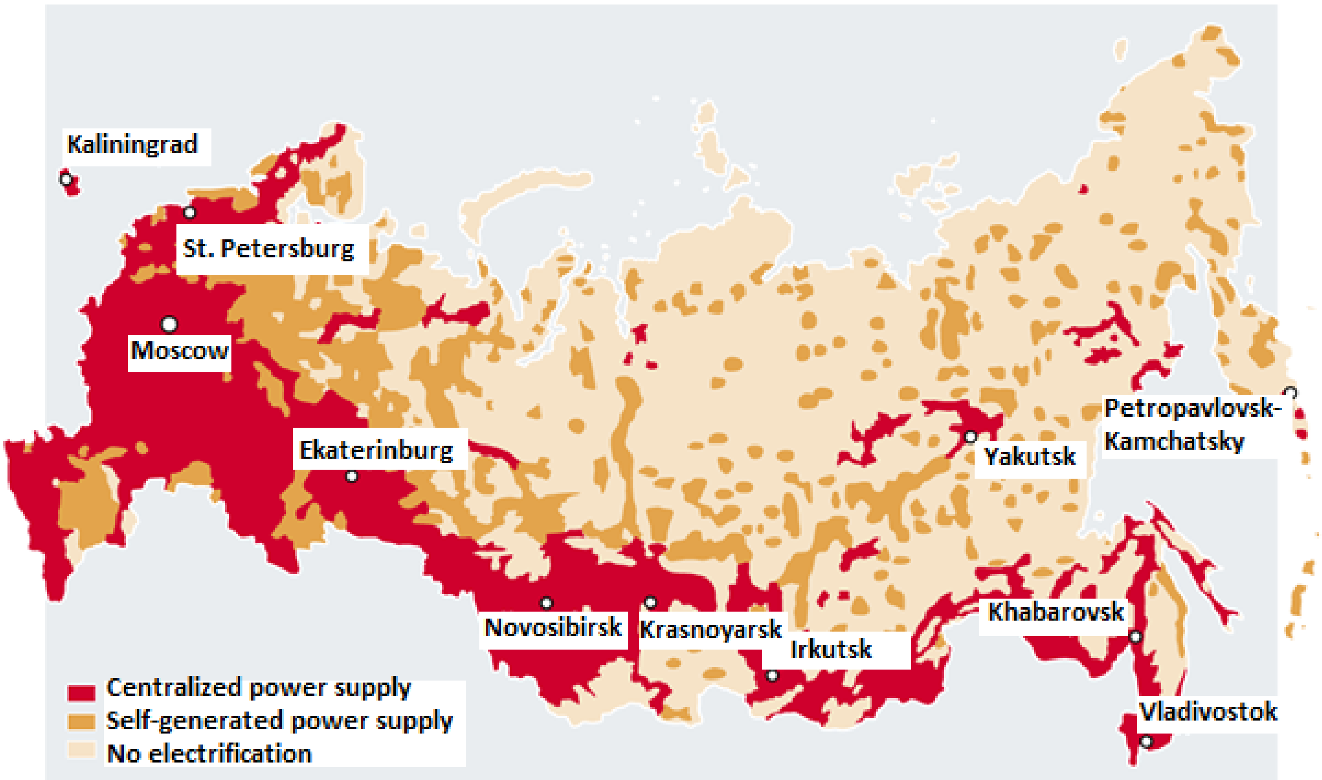

Fig. 1. The power supply scheme of the Russian Federation[1].[1]

1 Illustrations provided by the Department of Renewable Energy of SPbPU. Based on the materials of the International forum on electricity UPGrid.

World experience in implementing renewable energy sources.

The development of renewable energy today is a global trend, due to both the need to ensure the energy independence of countries and regions, and concern for the environment. According to the results of the past 2019, electricity consumption in Europe decreased by 2% (-56 TWh), returning the demand to the level of 2015. At the same time, the EU's gross domestic product grew by 1.4% over the past year.

The share of renewable energy sources (RES) in production of the European electricity reached the record of 34.6%. Solar and wind power together generated almost 18% of electricity (569 TWh), surpassing coal in power generation for the first time. The share of renewable energy sources in gross final energy consumption by EU Member States is shown in Fig. 2. The figure shows that many countries have already reached the 2020 target, although the year is far from over.

In just one year, coal-based electricity production in the European Union fell by 24%, and in 2019 was less than half of the level in 2007. Coal-based production decreased by 32%, and brown coal-based production decreased by 16%. As a result, European energy sector CO_2 emissions fell by 12% in 2019 — the largest drop since at least 1990.

Half of the coal generation was replaced by wind and solar power, and half by natural gas. The share of wind and solar generation has increased due to the installation of new capacities, while the growth of gas generation is due to higher CO_2 prices and lower gas prices, which has increased the competitiveness of gas-fired power plants compared to coal-fired ones. It shall be noted that in 2019, gas generation in terms of output was 8% lower than the record level in 2010.

Of course, there are also nuances of using renewable energy sources. For example, solar panels are useless in cloudy weather and at night, and wind farms are idle in windless weather. But even in these issues,

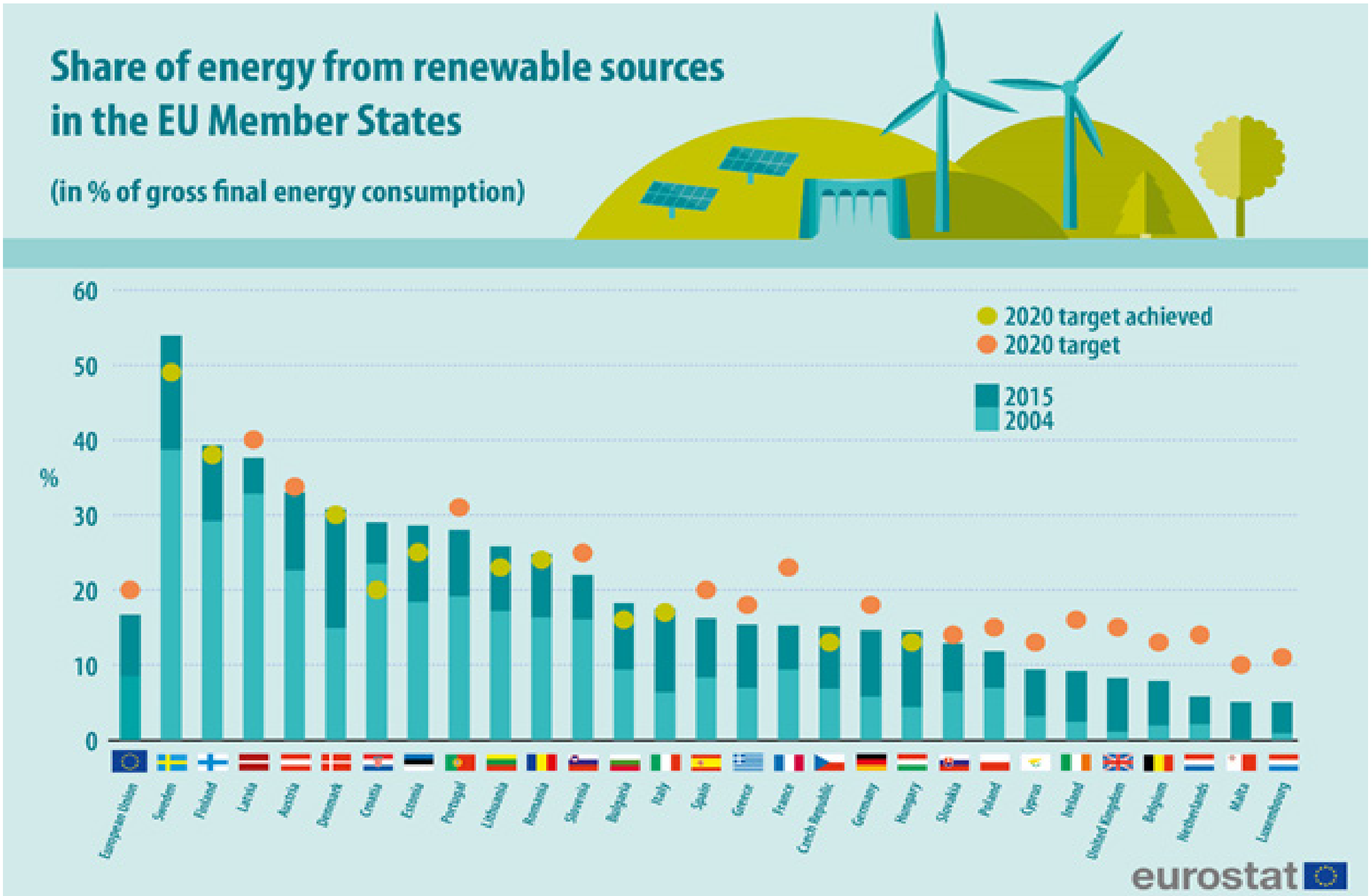

Fig. 2. Share of renewable energy sources in gross final energy consumption in the EU Member States: indicators for 2004, 2015 and 2020 (target and current value).[2]

2 According to ec.europa.eu/eurostat

the world energy community is constantly searching for solutions. Thus, in order to accumulate the generated electricity, more and more advanced batteries are being developed, the materials and technologies used are constantly being improved, and hybrid systems combining wind turbines, solar panels and, for example, diesel generator are being used to increase the efficiency of generation. Such system will help to offset the ups and downs of energy received from windmills and solar panels, and ensure overall reliability of operation.

At the same time, it is not only the European Union that shows its high interest in renewable energy sources. According to Bloomberg New Energy Finance, the trend of increasing the share of investments in various types of alternative energy is observed around the world. At the same time, as can be seen from Fig. 3, wind power is showing a constant and significant growth – as one of the most efficient and inexpensive sources of energy.

Importantly, the cost of electricity generated from renewable energy sources has already approached, and in many cases is lower than the cost of electricity generated by traditional methods (by burning hydrocarbons). The unsubsidized normalized cost of wind and solar energy is currently US $ 30-60 per 1 megawatt hour (MWh), which is lower than the price range for the cheapest fossil fuel, natural gas (US $ 42-78 per 1 MWh) [5].

According to the same Bloomberg New Energy Finance, the generation cost for onshore wind power plants and photovoltaic solar power plants has already fallen by 18% in the first half of 2018 [6].

Renewable energy sources for the Arctic.

The opportunities for RES development in the Arctic are dictated by nature itself. Thus, in the northernmost latitudes there is potential for the development of wind energy, and in a number of Eastern Arctic regions (for example, in Yakutia) – solar energy. The resource of renewable energy in the Arctic region is significant and its implementation will allow to provide 40-50% replacement of diesel fuel rather soon, and in the future, a larger volume. It is important to study the natural and economic opportunities for RES development in each case and make decisions considering all the identified parameters and characteristics of the territory.

Currently, the state of renewable energy

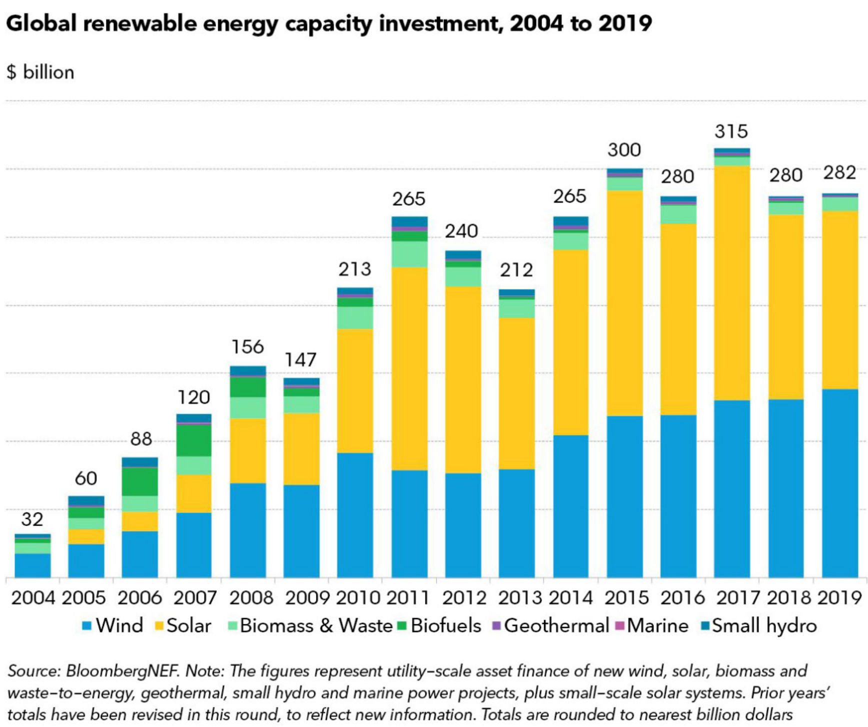

Fig. 3. Share of global investments in renewable energy from 2004 to 2010 in trillion dollars (wind, solar, biomass and waste, biofuels, geothermal sources, marine energy, small hydropower)[3].

3 According to Bloomberg New Energy Finance as per 2019

technologies in Russia is characterized by their weak development, especially in the regions of the Far North and the Arctic. However, the importance of renewable energy in the Arctic is increasing at the present time, and, as mentioned above, it is due to the high cost of traditional energy sources, as well as the need to reduce the burden on the environment – this is one of the most important global trends of our time. In order to increase the number of renewable energy projects in the Arctic zone of the Russian Federation, we need an effective regulatory framework, a favorable investment and tax climate, as well as a high level of state support.

Let us look into the existing system of RES electricity generation in the Arctic.

A common feature of the climate of the Northern regions is a long winter (up to 300 days a year) with frosts reaching -35-50°C. In the short (about 3 months) summer period, the temperature only sometimes rises up to +20°C. Stable and strong winds are observed here mostly in winter, as well as during the transition period (spring and autumn). This means that the potential for wind power development in the Northern regions is high.

There are two main directions of wind power development in the Far North:

1. The use of small wind power plants (WPL) for decentralized energy consumers, both separately and as part of hybrid power plants (together with solar panels and diesel generators). The most serious obstacle to the development of small wind power plants is the relatively high cost of wind installations. Today it is about 2-3 thousand US dollars for 1 kW of installed capacity. But, as mentioned above, according to the experience of developed countries, the payback period for such installations is on average 5-6 years. Thus, small wind power needs to be co-financed or subsidized by the state.
2. The use of wind power as part of the existing developed power grid. The US and EU have accumulated much experience in this issue. According to the Deloitte Center for Energy Solutions (USA), if previously there was no success in ensuring the stability of the overall power system with the use of wind turbines, today all problems are solved and the growth of solar-wind energy is accompanied by an increase in the reliability and stability of power systems [8]. RES either have virtually no effect on the operation of the power system or require minor changes to the operation and use of existing energy resources [9].

In a cold climate, the use of wind energy has several positive effects.

First, cold air has a higher density than warm air. In this regard, the energy efficiency of the installation at the same wind speed will be higher. Wind plant power (kW) is calculated as follows:

$$P = 4.81 * 10^{-4} E d^2 \rho \phi^3 \eta,$$

where E — is the utilization of wind energy (measure of the efficiency of the wind wheel and is a function of wind speed, the angle of twist of the blade wheel and the angular velocity of rotation of the wheel), d — is the diameter of the wind wheel, ρ — is the air density, ϕ — is the wind speed, η —is efficiency of the wind plant generator.

As per this equation, it follows that the power of a wind plant is proportional to the density of air ρ. Therefore, when the air temperature decreases, for example, from +15 to -15°C, the installation capacity increases by 11 %. At the same time, if there is a fall in atmospheric pressure, wind turbine power is also reduced (for example, when the pressure drop from 770 to 730 mm Hg, wind turbine power is reduced by 6%). Such dependencies indicate that obtaining additional wind power in unstable Arctic weather conditions is quite difficult.

Secondly, the Northern regions with a cold climate and a very long heating period are characterized by high specific consumption of electricity and heat.

Third, as mentioned above, in the Northern regions, prices for electricity and heat are much higher, due to the use of imported diesel fuel, fuel oil and coal at power plants.

All of the above should encourage the introduction of RES into local and centralized power supply systems in the Far North regions. It should be especially noted that in these regions, improving the comfort and living conditions of the population is much more important than in other regions of the country.

It is obvious that the efficient operation of wind power plants in the North requires the use of special materials (cold-resistant steel, synthetic low-temperature grease for bearings, special fluids for hydraulic systems) and operating technologies (heating the gearbox, blades and weather sensors to prevent icing and frost deposition). But even these necessary actions will not make the cost of electricity higher than when using traditional sources of its generation.

You might think that the use of solar cells (solar energy) in the Arctic region is unrealistic, but in fact, this is not the case. It is necessary to take into account the existence of the albedo effect in the Arctic (or diffuse reflection coefficient, which is way higher for white snow than for dark surfaces), as well as the fact that the potential for solar energy production increases in cold climates. It is known that the lower the ambient temperature, the more efficient solar cells become (efficiency increases by 0.5% °C). Thus, at 0°C, the efficiency of the solar cell is 10% higher than at 20°C. However, during the Polar night (in winter), the potential of solar energy in the Arctic region falls significantly. Thus, the energy system of the Arctic, of course, cannot completely depend on solar energy. For maximum efficiency, it is necessary to consider hybrid systems (a combination of renewable and traditional energy sources), as mentioned above.

Currently, in the Arctic zone, the construction of power plants based on renewable energy sources is carried out pointwise, in many cases in the format of an experiment. Here are some examples of renewable energy projects currently being implemented in the Arctic:

- Furniture factory "Green House" (since 2015) (Murmansk), capacity 500 kW.
- Fishing and tourist complex, Mudyug island, lighting system (since 2014), Arkhangelsk region, capacity 1.5 kW.
- "Polaris" project (implemented under the Kolarctic international program), with 4 wind power plants (since 2016), Nenets Autonomous district, capacity 200 kW.
- Anadyr wind plant on the Cape of Observation of the Anadyr district, 10 wind generators (since 2002), Chukotka Autonomous district, 2mW (Fig. 4).
- Experimental wind power station in Labytnangi (since 2014), Yamalo-Nenets Autonomous district, capacity 250 kW.
- The wind Park in Tiksi. It is a technological complex where wind power plants, diesel generators and

Fig. 4. Anadyr wind plant on the Cape of Observation of the Anadyr district (2mW) [4]

4 Photo https://www.drive2.ru/c/468787778692318135/

an electric power storage system are combined. The wind farm consists of 3 wind turbines with a total capacity of 900 kW. Diesel fuel economy is 500 tons per year [7].

- Wind farm "Zapolyarny", consisting of 6 wind generators (from 1993 to 2014), Komi Republic, capacity of 1.5 mW.
- Experimental wind power station "Bykov Mys" in Tiksi, Republic of Sakha (Yakutia), capacity 1.9 mW.
- Solar photovoltaic power plants in the following rural localities of Dulgalakh and Kudu-Kyuyol (2013), Batamay (since 2011), Dzhargalakh, Toyon-Ary (2014), Kuberganya, Eyik, Delgey, Batagay, Betenkyos, Ulu, Yunkyur (Fig. 5), the Upper Amga, Stolby, Innyakh (2015), Yamalo-Nenets Autonomous District, the total capacity of about 1.4 mW.

From the data provided, it can be seen that at the moment, renewable energy does not provide enough of the needs of the Arctic regions in electricity. Despite the huge potential of renewable energy sources in the Arctic, there are still very few projects implemented. According to official data, the total installed capacity of all wind and solar power plants in the Far North does not exceed 7-8 MW, i.e. it will not be able to provide electricity to even one of 1000 settlements with a population of more than 1 thousand people. However, the positive experience of the EU, USA and Japan described above shows that investing in renewable energy development is effective, and the development of renewable energy in the Arctic itself will lead to economic growth of the region, increase its attractiveness to the population and reduce the negative impact on the environment. In addition, as follows from the analysis of prof. I. A. Bashmakov [3], with tariffs of more than 20 rubles/kWh, almost all current renewable energy technologies are competitive, even with additional costs for their Northern implementation.

Such rapid growth of electricity production from renewable sources in the world developed countries became possible largely due to the creation of an effective regulatory framework for regulating the activities of energy market participants, the introduction of significant financial support measures, tax remissions, as well as the introduction of modern innovative technologies of smart small networks (smart grids), automation and blockchain technologies. In order to achieve the maximum effect when implementing RES in the Russian Arctic, it makes sense to take

Fig. 5. Solar power plant. Yunkur village, Verkhoyansky district, Republic of Sakha (Yakutia)[5].

5 Photo www.kemoblast.ru

advantage of the positive experience of countries that successfully implement such projects, and to use the achievements of domestic science.

Conclusions

The implementation of energy efficiency programs and the introduction of RES local power plants in the Arctic regions will allow us to:

- reduce the cost of delivering traditional fuel (diesel, fuel oil, coal),
- reduce the negative impact on the Arctic's fragile natural environment,
- reduce electricity tariffs for the population, industrial and municipal facilities,
- reduce government costs for subsidizing high electricity tariffs for the population, industrial and municipal facilities,
- increase the reliability and stability of power systems,
- increase the competitiveness of enterprises by reducing their energy supply costs,
- increase the attractiveness of the Arctic for the population by providing more comfortable living and working conditions,
- reduce the dependence of the Arctic on the so-called "Northern delivery".

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